# Claims

[c1] 1. An apparatus for processing an uncorrected radiograph comprising:

an X-ray scatter compensator; and

a controller coupled to said compensator,

wherein said compensator is configured for iteratively generating a refined value of a normalized estimated X-ray scatter signal corresponding to an uncorrected radiograph,

wherein said controller is configured for subtracting said refined value from a corresponding normalized total X-ray signal of said uncorrected radiograph so as to form a corresponding corrected radiograph.

[c2] 2. The apparatus of claim 1, wherein said uncorrected radiograph has a plurality of profiles and each of said profiles has a corresponding normalized total X-ray signal, wherein said compensator is further configured for iteratively generating a plurality of refined values, wherein said controller is further configured to subtract each of said refined values from a respective one of said plurality of normalized total X-ray signals so as to form said corresponding corrected radiograph.



[c3] 3. An apparatus for processing a collection of uncorrected radiographs comprising:

an X-ray scatter compensator; and

a controller coupled to said compensator, wherein said compensator is configured for iteratively generating a plurality of refined values, each corresponding to a profile of a corresponding one of said uncorrected radiographs,

wherein said controller is configured to subtract each of said refined values from a normalized total X-ray signal corresponding to said profile of said corresponding one of said uncorrected radiographs so as to form a collection of corrected radiographs.

[c4] 4. The apparatus of claim 3, wherein said controller is further configured for constructing an object representation from said collection of corrected radiographs.

[c5] 5. The apparatus of claim 3, wherein said compensator is further configured to generate at least one of said refined values by:

subtracting a normalized total X-ray signal of a side region of an air image radiograph from a corresponding normalized total X-ray signal of said side region of said uncorrected radiograph to generate a normalized side region estimated X-ray scatter signal;

generating a normalized central region estimated X-ray scatter signal by interpolation between corresponding values of said normalized side region estimated X-ray scatter signal next to said respective central region;

combining said normalized side region estimated X-ray scatter signal and said corresponding normalized central region estimated X-ray scatter signal to generate a current value of said normalized estimated X-ray scatter signal; and

low pass filtering said current value of said normalized estimated X-ray scatter signal to generate a low-pass filtered current value of said normalized estimated X-ray scatter signal.

[c6] 6. The apparatus of claim 5, wherein said compensator is further configured to generate a collection of pre-processed radiographs by, for each respective one of said uncorrected radiographs, subtracting said low-pass filtered current value of said normalized estimated X-ray scatter signal from said normalized total X-ray signal.

[c7] 7. The apparatus of claim 6, wherein said compensator is further configured to generate each of said refined values by processing said collection of pre-processed radiographs with a reconstruction algorithm to produce a three-dimensional reconstructed image.

[c8]

8. The apparatus of claim 7, wherein said compensator is further configured to generate said refined values by generating a three-dimensional thresholded image by comparing a three-dimensional reconstructed image pixel value with threshold value, wherein said three-dimensional reconstructed image pixel value is replaced with said threshold value if said three-dimensional reconstructed image pixel value exceeds said threshold value, and said three-dimensional reconstructed image pixel value is replaced with zero if said three-

dimensional reconstructed image pixel value is below said threshold value.

[c9] 9. The apparatus as in claim 8, wherein said compensator is further configured to generate each of said refined values by forward projecting said three-dimensional thresholded image to generate a collection of idealized radiographs.

[c10] 10. The apparatus of claim 9, wherein the compensator is further configured to generate each of said refined values by:
simulating a corresponding three-dimensional geometry of an imaging system comprising, a simulated X-ray detector, a simulated X-ray beam and said three-dimensional thresholded image, wherein said simulated X-ray beam further comprises a plurality of simulated X-rays intersecting a representation of said object in said three-dimensional thresholded image, wherein said corresponding simulated X-rays that intersect said representation of said object extend from said simulated X-ray source to said simulated X-ray detector element in an array of said simulated X-ray detector elements in said simulated X-ray detector;
computing a path length for each of said corresponding simulated X-rays that intersects said representation of said object, wherein said path length extends from where said simulated X-ray enters said representation of said object to where said simulated X-ray exits said representation of said object;
calculating a normalized intensity signal by taking an exponential of the negative product of each of said path lengths through said three-dimensional thresholded image for each of corresponding said simulated X-rays and said respective linear attenuation coefficient; and
calculating each of said estimates of said normalized primary X-ray signal for each of said corresponding idealized radiographs.

[c11] 11. The apparatus of claim 9, wherein said compensator is further configured to generate each of said refined values by subtracting each idealized radiograph of said collection of idealized radiographs from said corresponding normalized total X-ray signal of said respective one of said uncorrected radiographs to generate a collection of noisy representations of said normalized estimated X-

ray scatter signal.

[c12] 12. The apparatus of claim 11, wherein said compensator is further configured to generate each of said refined values by low-pass filtering said noisy representations of said normalized estimated X-ray scatter signal.

[c13] 13. The apparatus of claim 12, wherein said compensator is further configured to generate each of said refined values by:
subtracting said refined value of said normalized estimated X-ray scatter signal from said low-pass filtered current value of said normalized estimated X-ray scatter signal to compute a difference signal;
squaring said difference signal to create a squared difference signal;
suming said squared difference signal over an array of detector elements in an X-ray detector to create a metric;
comparing said metric against a quality value;
setting said low-pass filtered current value of said normalized estimated X-ray scatter signal equal to said refined value of said normalized estimated X-ray scatter signal; and
iteratively generating said refined value of said normalized estimated X-ray scatter signal of said corresponding ones of said uncorrected radiographs until said metric falls below said quality value for each of said uncorrected radiographs in said collection of uncorrected radiographs.

[c14] 14. The apparatus of claim 3, wherein said compensator is further configured for iteratively generating each of said refined values corresponding for said profile in each uncorrected radiograph in a collection of uncorrected radiographs, wherein said controller is further configured to subtract said refined value from said corresponding normalized total X-ray signal of said profile in each of said uncorrected radiographs so as to form a collection of corrected radiographs.

[c15] 15. The apparatus of claim 14, wherein said controller is further configured for constructing an object representation from said collection of corrected radiographs.

[c16] 16. An apparatus for determining a refined value of a normalized estimated X-ray scatter signal for each corresponding uncorrected radiograph of a collection of uncorrected radiographs, produced by placing an object between an X-ray detector and an X-ray source, wherein said X-ray source generates an X-ray signal comprising:

an X-ray scatter compensator, said compensator further comprising;

(a) an X-ray scatter signal estimate initiator configured for:

subtracting a normalized total X-ray signal of a side region of an air image radiograph from a corresponding normalized total X-ray signal of said side region of said corresponding uncorrected radiograph to calculate a normalized side region estimated X-ray scatter signal;

generating a normalized central region estimated X-ray scatter signal by interpolation between corresponding values of said normalized side region estimated X-ray scatter signal next to said respective central region;

combining said normalized side region estimated X-ray scatter signal and said corresponding normalized central region estimated X-ray scatter signal to generate a current value of said normalized estimated X-ray scatter signal;

low pass filtering said current value of said normalized estimated X-ray scatter signal to generate a low-pass filtered current value of said normalized estimated X-ray scatter signal;

(b) a pre-processed radiograph generator configured to generate a collection of pre-processed radiographs by, for each respective one of said uncorrected radiographs, subtracting said low-pass filtered current value of said normalized estimated X-ray scatter signal from said normalized total X-ray signal;

(c) a volumetric reconstructed image generator configured for producing a three-dimensional reconstructed image of said object from said collection of pre-processed radiographs utilizing a reconstruction algorithm;

(d) a thresholded image generator configured for thresholding said three-dimensional reconstructed image to generate a corresponding three-dimensional thresholded image;

(e) an idealized radiograph generator configured for forward projecting said three-dimensional thresholded image to generate a collection of idealized radiographs;

(f) a noisy X-ray scatter signal generator configured for subtracting each one of said idealized radiographs from said corresponding normalized total X-ray signal of said respective ones of said uncorrected radiographs to generate a collection of noisy representations of said normalized estimated X-ray scatter signal;

(g) a low-pass filtered X-ray scatter generator configured for removing high frequency signal components from each of said noisy representations of said corresponding normalized estimated X-ray scatter signal to generate said refined value of said normalized estimated X-ray scatter signal for each of said uncorrected radiographs; and

(h) an error summation generator configured for:

subtracting said refined value of said normalized estimated X-ray scatter signal of each of said corresponding uncorrected radiographs from said low-pass filtered current value of said corresponding normalized estimated X-ray scatter signal to compute a difference signal;

squaring said difference signal to create a squared difference signal;

summing said squared difference signal over an array of detector elements of said X-ray detector to create a metric;

comparing said metric against a quality value; and

setting said low-pass filtered current value of said normalized estimated X-ray scatter signal equal to said refined value of said normalized estimated X-ray scatter signal,

(i) said compensator further configured for iteratively processing paragraph (b) through paragraph (h) to generate said refined value of said normalized estimated X-ray scatter signal of said corresponding ones of said uncorrected radiographs until said metric falls below said quality value for each of said uncorrected radiographs in said collection of uncorrected radiographs.



[c17]

17. The apparatus of claim 16, wherein said thresholded image generator is configured for:

comparing each of corresponding three-dimensional reconstructed image pixel values with a threshold value;

replacing each of said three-dimensional reconstructed image pixel values with

said threshold value if said three-dimensional reconstructed image pixel value exceeds said threshold value;
replacing each of said three-dimensional reconstructed image pixel values with zero if said three-dimensional reconstructed image pixel value is below said threshold value; and
producing said three-dimensional thresholded image.

[c18] 18. The apparatus of claim 16, wherein said idealized radiograph generator is configured for forward projecting said three-dimensional thresholded image, wherein said idealized radiograph generator is also configured for:
simulating a corresponding three-dimensional geometry of an imaging system comprising, a simulated X-ray detector, a simulated X-ray beam and said three-dimensional thresholded image, wherein said simulated X-ray beam further comprises a plurality of simulated X-rays intersecting a representation of said object in said three-dimensional thresholded image, wherein said corresponding simulated X-rays that intersect said representation of said object extend from said simulated X-ray source to said simulated X-ray detector element in an array of said simulated X-ray detector elements in said simulated X-ray detector;
computing a path length for each of said corresponding simulated X-rays that intersects said representation of said object, wherein said path length extends from where said simulated X-ray enters said representation of said object to where said simulated X-ray exits said representation of said object;
calculating a normalized intensity signal by taking an exponential of the negative product of each of said path lengths through said three-dimensional thresholded image for each of corresponding said simulated X-rays and said respective linear attenuation coefficient; and
calculating each of said estimates of said normalized primary X-ray signal for each of said corresponding idealized radiographs.

[c19] 19. The apparatus of claim 18, wherein said idealized radiograph generator is configured for forward projecting said three-dimensional thresholded image to generate a plurality of said idealized radiographs at less than every said X-ray detector element.

[c20] 20. The apparatus of claim 19, wherein said idealized radiograph generator is configured for forward projecting said three-dimensional thresholded image to generate said collection of idealized radiographs at every other said X-ray detector element.

[c21] 21. The apparatus of claim 19, wherein said idealized radiograph generator is configured for forward projecting said three-dimensional thresholded image to generate said collection of idealized radiographs at every third said X-ray detector element.

[c22] 22. The apparatus of claim 18, wherein said idealized radiograph generator is configured for forward projecting said three-dimensional thresholded image to generate said collection of idealized radiographs at less than every view of said object.

[c23] 23. The apparatus of claim 22, wherein said idealized radiograph generator is configured for forward projecting said three-dimensional thresholded image to generate said collection of idealized radiographs at every other view of said object.

[c24] 24. The apparatus of claim 22, wherein said idealized radiograph generator is configured for forward projecting said three-dimensional thresholded image to generate said collection of idealized radiographs at every third view of said object.

[c25] 25. A method for processing an uncorrected radiograph comprising:
iteratively generating a refined value of a normalized estimated X-ray scatter signal corresponding to an uncorrected radiograph; and
subtracting said refined value of said normalized estimated X-ray scatter signal from a corresponding normalized total X-ray signal of a respective one of said uncorrected radiographs so as to form a corresponding corrected radiograph.

[c26] 26. The method of claim 25, wherein said uncorrected radiograph has a plurality of profiles and each of said profiles has a corresponding normalized total X-ray signal, further comprising;
iteratively generating a plurality of refined values, wherein each of said refined

values corresponds to a respective portion of said uncorrected radiograph; and subtracting each of said refined values from a respective one of said plurality of normalized total X-ray signals so as to form said corresponding corrected radiograph.

[c27] 27. A method for processing a collection of undercorrected radiographs comprises:
iteratively generating a refined value of a normalized estimated X-ray scatter signal corresponding to each profile of uncorrected radiographs in each of said collection of uncorrected radiographs;
subtracting each of said refined values from a corresponding normalized total X-ray signal for each profile in each of said uncorrected radiographs so as to form a collection of corrected radiographs; and
constructing an object representation from said collection of corrected radiographs.

[c28] 28. A method for generating a refined value of a normalized estimated X-ray scatter signal in three-dimensional reconstructed images comprises:
(a) subtracting a normalized total X-ray signal of a side region of an air image radiograph from said corresponding normalized total X-ray signal of said side region of an uncorrected radiograph, in a collection of uncorrected radiographs, produced by irradiating an object to generate a normalized side region estimated X-ray scatter signal;
generating a normalized central region estimated X-ray scatter signal by interpolation between corresponding values of said normalized side region estimated X-ray scatter signal next to said respective central region;
combining said normalized side region estimated X-ray scatter signal and corresponding said normalized central region estimated X-ray scatter signal to generate a current value of said normalized estimated X-ray scatter signal;
low pass filtering said current value of said normalized estimated X-ray scatter signal to generate a low-pass filtered current value of said normalized estimated X-ray scatter signal;
(b) subtracting said low-pass filtered current value of said normalized estimated X-ray scatter signal from said normalized total X-ray signal of respective ones

of said collection of uncorrected radiographs and generating a collection of preprocessed radiographs;

(c) generating a three-dimensional reconstructed image from said collection of pre-processed radiographs using a reconstruction algorithm;

(d) thresholding said three-dimensional reconstructed image utilizing a threshold value to produce a three-dimensional thresholded image;

(e) forward projecting said three-dimensional thresholded image to generate a collection of idealized radiographs;

(f) calculating a collection of noisy representations of said normalized estimated X-ray scatter signal by subtracting each one of said idealized radiographs from said corresponding normalized total X-ray signal of said respective ones of said uncorrected radiographs;

(g) low pass filtering said noisy representation of said normalized estimated X-ray scatter signal to produce said refined value of said normalized estimated X-ray scatter signal for each of said uncorrected radiographs;

(h) subtracting said refined value of said normalized estimated X-ray scatter signal of each of said corresponding uncorrected radiographs from said low-pass filtered current value of said normalized estimated X-ray scatter signal to compute a difference signal;

(i) squaring said difference signal to create a squared difference signal and summing said squared difference signal over an array of detector elements in an X-ray detector to create a metric;

(j) comparing said metric against a quality value, and setting said low-pass filtered current value of said normalized estimated X-ray scatter signal to said refined value of said normalized estimated X-ray scatter signal; and

(k) repeating step b through step j to generate said refined value of said normalized estimated X-ray scatter signal of said corresponding ones of said uncorrected radiographs, until said metric falls below said quality value for each of said uncorrected radiographs of said collection of uncorrected radiographs.



[c29]

29. The method of claim 28, wherein said step of thresholding said three-dimensional reconstructed image to generate said thresholded three-dimensional image is accomplished by comparing each three-dimensional

reconstructed image pixel value with a threshold value, where said three-dimensional reconstructed image pixel value is replaced with said threshold value if said three-dimensional reconstructed image pixel value exceeds said threshold value, and said three-dimensional reconstructed image pixel value is replaced with zero if said three-dimensional reconstructed image pixel value is below said threshold value.

[c30] 30. The method of claim 28, wherein said step of forward projecting said thresholded image to produce each of said idealized radiographs further comprises:

simulating a corresponding three-dimensional geometry of an imaging system comprising a simulated X-ray detector, a simulated X-ray beam and said three-dimensional thresholded image, wherein said simulated X-ray beam further comprises a plurality of simulated X-rays intersecting a representation of said object in said three-dimensional thresholded image, wherein said corresponding simulated X-rays that intersect said representation of said object extend from said simulated X-ray source to said simulated X-ray detector element in an array of said simulated X-ray detector elements in said simulated X-ray detector;

computing a path length for each of said corresponding simulated X-rays that intersects said representation of said object, wherein said path length extends from where said simulated X-ray enters said representation of said object to where said simulated X-ray exits said representation of said object for each of said idealized radiographs;

calculating a normalized intensity signal by taking an exponential of the negative product of each of said path lengths through said three-dimensional thresholded image for each of corresponding said simulated X-rays and said respective linear attenuation coefficient; and

calculating each of said estimates of said normalized primary X-ray signal for each of said corresponding idealized radiographs.

[c31] 31. The method of claim 30, wherein said step of generating idealized radiographs is performed at less than every said X-ray detector element.

[c32] 32. The method of claim 30, wherein said step of generating idealized radiographs is performed at every other said X-ray detector element.

[c33] 33. The method of claim 30, wherein said step of generating idealized radiographs is performed at every third said X-ray detector element.

[c34] 34. The method of claim 30, wherein said step of generating idealized radiographs is performed at less than every view of said object.

[c35] 35. The method of claim 30, wherein said step of generating idealized radiographs is performed at every other view of said object.

[c36] 36. The method of claim 30, wherein said step of generating idealized radiographs is performed at every third view of said object.